1,198,410

PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Antennae

We, OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES (O.N.E.R.A.), a Body Corporate organised under the laws of France, of 29 Avenue de la Division Leclerc, Chatillon-Sous-Bagneux, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

The invention relates to antennae for receiving or transmitting radio-electric signals, more particularly to helical antennae earthed at one end, the dimensions of the antenna being very small, both axially and transversely, with respect to the average operating wavelength.

Generally speaking, it is important to reduce the size of antennae until they are very small with respect to the operating wavelength, since the antennae can then be disposed in a restricted space, their weight can be reduced, and their mechanical rigidity can be increased.

The invention relates to antennae having a single conductor wound into a cylindrical or conical helix and transmitting a wave whose electric field is linearly polarised in a direction parallel to the helix axis, giving a radiation polar diagram which is practically circular in a plane perpendicular to the axis, the antennae being extremely small compared with the mid-band operating wavelength in free space, but being capable of having a great variety of external shapes and thus being very easy to adapt to a wide range of operating conditions though their efficiency is very nearly equal to that of a conventional half-wave dipole, the antennae operating at high efficiency when they are connected by a coaxial line to a transmitter or receiver.

The electrical properties of such antennae, at least for the case of cylindrical helical antennae, have been studied in a paper entitled "Wide-frequency-range tuned helical antennas and circuits" by A. G. Kandoian and W. Sichak published in the American review "Convention Record of the I.R.E." 1953, pages 42 to 47. It can be shown, from the calculations given in the latter paper and in other publications that the optimal dimensioning of such antennae can be determined by applying the following simple rules.

For an antenna comprising a single conductor helically wound round a three-dimensional surface having a longitudinal axis, one terminal part of the conductor being connected to a conductor earth plane, a second terminal part being insulated, and the antenna comprising means for coupling it to a load circuit, the optimal dimensioning may be characterised in that, if λ denotes the wavelength in free space corresponding to the mid-band operating frequency and l denotes the total length of the wound conductor, λ and l satisfy the relation

$$0.3\lambda \leqslant l \leqslant 0.45\lambda$$

and that the said coupling means are coupled to the conductor along part of the conductor having the said first terminal part at one end, the length of the part being equal to a very small fraction of the wavelength λ, for instance 1/200 of said wavelength.

To clarify ideas, the expression "very small fraction of the operating wavelength" implies that the diameter of the helical windings is not more than one hundredth of the wavelength in free space, and the axial height is as small as one fiftieth of the wavelength.

In the case of a cylindrical helix, experiments by the Applicants have shown that the height and diameter of the ideal cylinder on

which the helical conductor is wound can be varied within wide limits, provided that the product of the number of turns N and the diameter d of the cylinder is between one-seventh and one-tenth of the wavelength λ in free space at the operating frequency, i.e.:

$$\lambda/10 \leqslant Nd \leqslant \lambda/7$$

or

$$0.10 \leqslant Nd/\lambda \leqslant 0.14 \qquad (1)$$

If the pitch of the helix is considerably smaller than the cylinder diameter, the quantity $(N\pi d)$ represents the length l of the antenna wire; in antennae according to the invention, therefore, the ratio l/λ satisfies the condition:

$$0.30 \leqslant l/\lambda \leqslant 0.45 \qquad (2)$$

If the helix is conical and not cylindrical, the quantity d should be replaced by the arithmetical mean of the diameters of the first and last turn in the helix.

According to the present invention, therefore, there is provided an antenna comprising a single conductor helically wound round a surface extending in three dimensions and having a longitudinal axis, one terminal part of the conductor being connected to a point of a conductor earth plane and a second terminal part being insulated, and means for coupling the antenna to a load circuit, in which antenna, if λ denotes the wave length in free space corresponding to the midband operating frequency and l denotes the total length of the wound conductor, λ and l satisfy the relation

$$0.3\lambda \leqslant l \leqslant 0.45\lambda$$

the said coupling means are coupled to the conductor along part of the conductor having the said point at one end, the length of such part being equal to not more than 1/100 of the wavelength λ, and the said conductor is stuck to a flexible sheet of dielectric material which is wound until the edges overlap and is kept in position by clamping, sticking or other suitable means.

According to a preferred embodiment of the invention, the said conductor is a thin metal strip.

According to another embodiment of the invention, the said conductor is a thin metal strip and is produced by coating part of the surface of the dielectric sheet with metal.

According to still another embodiment of the invention, the said conductor is a thin metal strip and is produced by the technique of printed circuits.

In order that the invention may be clearly understood embodiments thereof will now be described in more detail, by way of example only, with reference to the accompanying drawings, in which:

Figures 1 to 5 show antennae of the prior art; and

Figures 6 to 10, 11a and 11b, and 12 to 14 illustrate antennae embodying the invention.

Referring firstly to Figure 1, a conventional antenna of conical helical shape, which can be disposed in a missile head, is shown in Figure 1. A conductor 41, whose unwound length is approximately 0.4 λ, is wound into a conical helix, the cone containing the central line of the conductor, which has a base approximately $\lambda/40$ in diameter and a height of approximately $\lambda/25$. The conductor is driven at point 47, near earthed end 46, by the inner conductor of coaxial line 43, the outer conductor 44 of which is connected to earth 45. An adjustable capacitor 48 is used for tuning, one plate being connected to a point 42 on conductor 41 and the other plate being connected to earth 45. The antenna has a pass band at 3 dB of attenuation of 3% of the operating frequency, and the efficiency is less than 0.5 dB below that of a half-wave dipole.

Experiments by the Applicants on known antennae have shown that the size and shape of helical antennae can be varied within very wide limits without affecting their optimum performance at wavelengths much greater than their size — i.e., the antennae can be adapted in the most efficient manner to the conditions for particular applications, e.g. can be given the required rigidity and appearance and can be disposed in a required space, etc., provided that the conditions expressed by the relation (1) between the product Nd and the wavelength are precisely adhered to.

Fig. 2 shows a first type of conventional cylindrical antenna.

A silver-coated brass conductor wire 51, 2 mm in diameter, is rolled into a helix on a support 52. The support consists of two plates 53, 54 perpendicular to one another and made of laminated plastics. The two plates form a sort of cylinder, coaxial with the antenna. The cylinder on which the helix is wound is 50 mm in diameter and 100 mm high. There are five turns and the length of wire is approximately 80 cm. The support is fixed on a brass baseplate 55 which acts as an earth and is 2 mm thick and 70 mm in diameter.

The antenna is designed to operate at a frequency of 137 MHz, i.e. at a wavelength $\lambda = 2.18$ m. It can be seen that

$$\frac{Nd}{\lambda} = \frac{0.25}{2.18} = 0.114$$

and that

$$\frac{l}{\lambda}=\frac{0.80}{2.18}=0.37$$

The inner conductor of the coaxial supply line 56 is connected to the antenna wire at a point 57 approximately 1 cm from the earthed end 59 of the wire. As a result, the distance between the earthed end and the drive point is approximately 1/200 of the wavelength.

The antenna in Fig. 2 is very nearly as efficient as a half-wave dipole, the difference being between 0.5 and 1 dB and the pass band is of the order of 1% of the average operating frequency.

In the variant shown in Fig. 3, the surface containing the central line of the conductor is not a cylinder but a truncated cone, which flares out more than in Fig. 1. The antenna is as efficient as that shown in Fig. 2, provided that relation (1) is adhered to, where *d* is the arithmetical mean of the base diameters of the truncated cone. In the antenna shown in Fig. 3, 61 denotes the antenna wire, 65 the earth level, 66 the inner conductor of the coaxial supply line, 67 the drive point, 68 the coaxial line and 69 the earthed bottom end of the antenna.

Experiments have also shown that helical antennae having a great variety of shapes (the surface containing the central line of the conductor can, for example, be a truncated cone having ellipsoidal bases) give equally satisfactory results provided that relation (1) is observed, where *d* is the average diameter defined as:

$$d=\frac{d_1+d_2+d_3+d_4+d_5+d_6}{6}$$

d_1 and d_2 being the axes of the ellipse forming the major base, d_5 and d_6 being the axes of the ellipse forming the minor base, and d_3 and d_4 the axes of the ellipse halfway between the bases.

The antennae can have ancillary apparatus for adjusting the resonance frequency or impedance, or for reducing the dimensions without affecting the performance. The auxiliary facilities, which are described below, are applied for simplicity to the cylindrical antenna only, as shown in Fig. 2, but they can of course also apply to the variant shown in Fig. 3.

According to a first auxiliary arrangement, shown in Fig. 4, a fixed or variable capacitor 91 is connected at one end to a point 92 on the conductor acting as the antenna, and at the other end to earth 55. Independently or in combination, another capacitor 93 can be inserted in series in conductor 51. The capacitors can be used to adjust the resonance frequency of the antenna in its operating range.

Fig. 5 shows a second auxiliary facility, this time for driving the antenna by magnetic coupling. The central conductor of coaxial line 58 is parallel to, but not connected to, conductor 51 for a length 101 which can be adjustable and is connected to earth 55 at the point 102. The distance between length 101 and conductor 51 can also be adjustable. The antenna impedance can also be matched with the impedance of the coaxial line. Fig. 5 shows telescopic separating members 103 for keeping the required distance between wires 51 and 101.

A description will now be given of antennae embodying the invention:

Known helical antennae are made sufficiently rigid for operating conditions, either through the intrinsic rigidity of the conductor of which they are made, or by auxiliary elements such as masts, stays and braces or by being wound round an insulating former. These elements complicate the structure, are unsightly, increase the weight and expense of the antennae, and are difficult to manufacture, especially in a mass-production process, when the antennae need to have small dimensions.

The invention aims to provide light, shapely antennae which are extremely rigid and which have perfectly reproducible characteristics.

Antennae embodying the invention can comprise matching and adjusting elements such as "roofs" and variable or fixed capacitors, and can be embedded in a material such as a polymerisable resin, having a suitable colour and external shape, so that the resulting appearance is suitable for each particular application.

In carrying out the invention, a conical or cylindrical helical antenna is manufactured by rolling a flexible sheet of a dielectric, to whose surface a thin metal conductor tightly adheres.

In the cylindrical antenna body shown in Figs. 6 and 7, a conducting strip 211 cut from a thin sheet of metal, e.g. copper, is tightly glued or stuck by any other known method of manufacturing printed circuits on to a rectangular sheet 210 of flexible dielectric material such as laminated fibre glass and epoxy resin. The sheet 211 is then rolled into a right cylinder. The resulting cylinder is held in position by clamping, riveting, glueing or any other suitable method. In Figs. 6 and 7, the terminal connections and coupling means are omitted for simplicity.

The dimensions of sides 212, 213, 214, and 215 of dielectric sheet 210, the length of conductor 211 and its slope 216 are chosen so that the cylinder obtained by rolling the sheet round an axis parallel to sides 214 and 215 comprises a number of successive layers equal to the number of turns in the helix being

manufactured. In Fig. 7, for example, the antenna body comprises three layers of dielectric sheet 210, so that conductor 211 forms a helix having three turns.

Figs. 8 and 9, which correspond to Figs. 6 and 7, show a similar cylindrical helical antenna having a number of matching and adjusting components.

Conductor 221 which is similar to conductor 211 is extended along part of sides 222 and 223 of dielectric sheet 220 by end bars 224 and 225, and has a connecting leg 226 extending perpendicularly towards bar 225. A terminal strip 227 is disposed near end bar 225.

Dielectric sheet 220 is rolled in the same manner as sheet 210 to give the tubular antenna body shown in Fig. 9.

In Fig. 9, end bar 224 of conductor 221 is connected to a brass component or "roof" 231 by a circular weld 232. End bar 225 is similarly connected to a brass baseplate 233. The antenna is driven by a coaxial cable whose inner conductor 234 is connected, e.g. by welding, to terminal strip 227, and the external conductor 235 is connected to baseplate 233 by a connection 236.

Terminal strip 227 is connected to end bar 225 by an inductive coupling conductor 237.

An adjustable tuning capacitor 238 is connected between leg 226 and baseplate 233.

Fig. 10 is a cross-section of the antenna diagrammatically shown in Fig. 9.

As Fig. 10 shows, the end bar 224 of conductor 221 is connected to brass roof 231 by circular weld 232, and end bar 225 is connected to baseplate 233. Plate 233 is a solid brass disc formed with a circular groove 330 for receiving the lower part of the tubular antenna body. Baseplate 233 is fixed by locking or welding bar 225 in groove 330.

The opposite end of the baseplate is prolonged by a threaded shank 331 for attaching the antenna to a support by tightening a nut 332. Threaded shank 331 is formed with a borehole 333 terminating in a device 334 for gripping and holding the coaxial cable supplying power to the antenna. The inner conductor 234 of the coaxial cable is connected to terminal strip 227, and the outer conductor 235 is connected to baseplate 233.

An opening 241 through the successive layers of dielectric sheet 220 gives access to the component for adjusting the tuning capacitor 238 disposed inside the antenna body. After being adjusted, the said component and the connection inside the antenna body can be held in position by embedding them e.g. in a polymerisable resin 242.

In a variant shown in Figs. 11a and 11b, which illustrate the antenna body only, parallel conductors 251 are disposed on each side of a dielectric sheet 250. The conductors on each surface are, respectively, symmetrical with respect to the plane passing through the middle of the thickness of the dielectric.

The slope 254 of the conductors is such that, after the dielectric sheet has been rolled into a single turn, the ends of the conductors on one surface overlap the ends of the conductors on the other surface so as to form the helix shown in Fig. 12. The conductors are connected by welding at points 255.

Rectangular spare lengths 252, 253 without conductors are disposed at each end of sheet 250 so as to hold the antenna body in position, e.g. by clamping or glueing.

Figs. 13 and 14, which are similar in principle to Figs. 6 and 7, show two essential stages in the manufacture of a conical helical antenna. Fig. 13 shows the unfolded surface of a truncated cone having a circular base and made from a dielectric sheet 260 having a conductor 261 stuck to its surface. Fig. 14 shows the trunco-conical antenna body formed by rolling dielectric sheet 260 until the ends overlap.

The examples described are cylindrical or conical helical antennae having a circular base and a constant pitch. These embodiments, of course, are in no way limitative and the invention can be applied to the manufacture of cylindrical or trunco-conical helical antennae having a non-circular, e.g. elliptical, base and/or a variable pitch.

More particularly, in the case of Figs 13 and 14 where, owing to its non-rectilinear shape, the conductor cannot be manufactured in the form of a straight metal strip stuck to a sheet of dielectric material, part of the surface of the sheet can be coated with metal, e.g. in the manner used for printed circuits.

WHAT WE CLAIM IS:—

1. An antenna comprising a single conductor helically wound round a surface extending in three dimensions and having a longitudinal axis, one terminal part of the conductor being connected to a point of a conductor earth plane and a second terminal part being insulated, and means for coupling the antenna to a load circuit, in which antenna, if λ denotes the wave length in free space corresponding to the mid-band operating frequency and l denotes the total length of the wound conductors, λ and l satisfy the relation

$$0.3\lambda \leqslant l \leqslant 0.45\lambda$$

the said coupling means are coupled to the conductor along part of the conductor having the said point at one end, the length of such part being equal to not more than 1/100 of the wavelength λ, and the said conductor is stuck to a flexible sheet of dielectric material which is wound until the edges overlap and is kept in position by clamping, sticking or other suitable means.

2. An antenna according to claim 1, in

which the said conductor is a thin metal strip.

3. An antenna according to claim 1, in which the said conductor is a metal strip and is produced by coating part of the surface of the dielectric sheet with metal.

4. An antenna according to claim 1, comprising auxiliary matching and adjusting elements such as capacitive load elements and fixed capacitors which, after the adjustment has been made, are held in position by immersing them in a fusible or polymerisable dielectric substance.

5. An antenna substantially as hereinbefore described with reference to and as illustrated in Figs. 6 to 10, 11a and 11b, and 12 to 14 of the accompanying drawings.

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Fig. 1

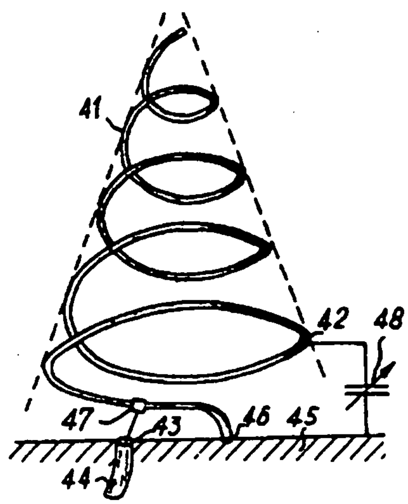


Fig. 2

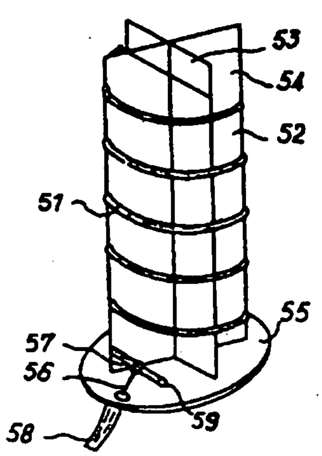
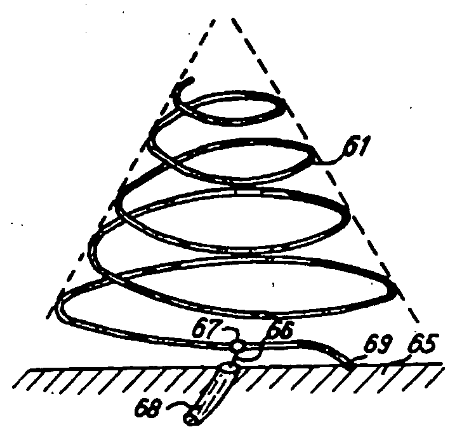


Fig. 3



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SHEET 2

Fig.4

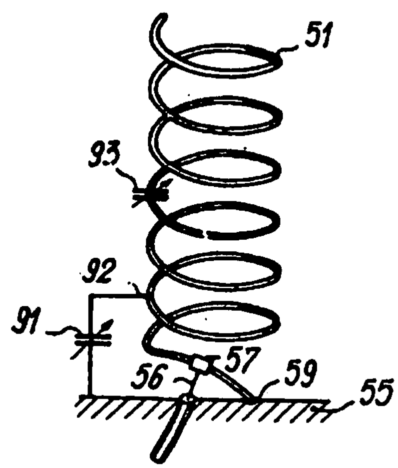
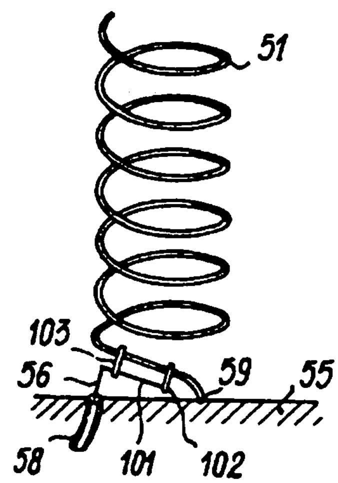


Fig.5



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SHEET 3

Fig. 6

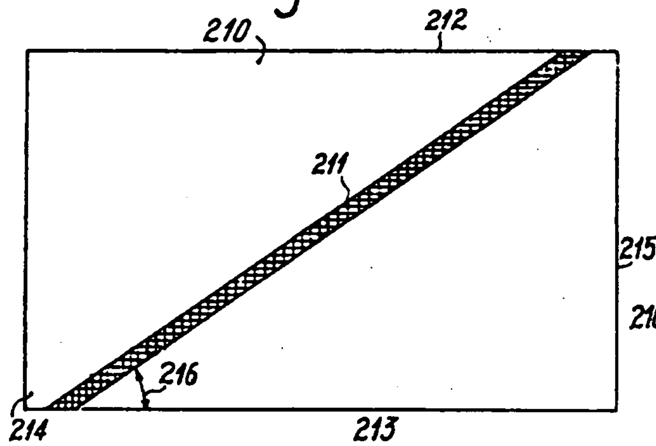


Fig. 7

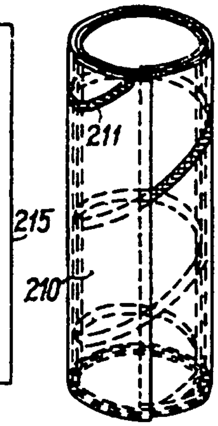


Fig. 8

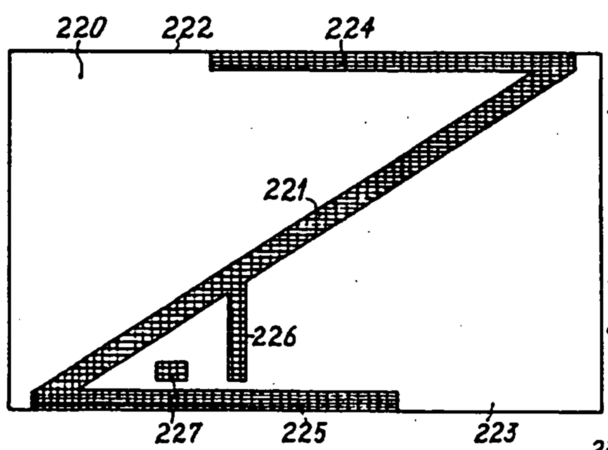
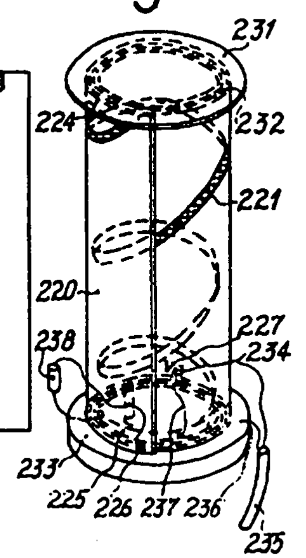


Fig. 9



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SHEET 4

Fig. 10

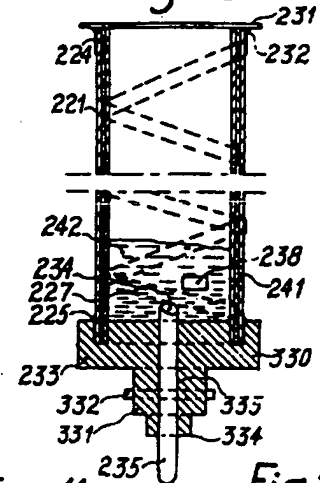

Fig. 11 a

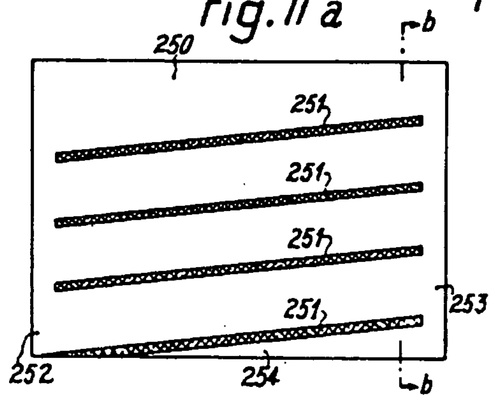

Fig. 11 b

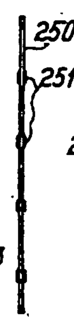

Fig. 12

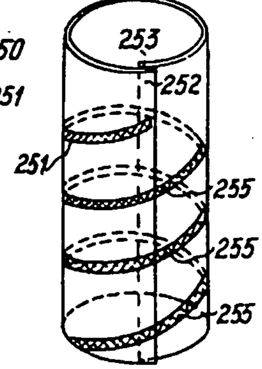

Fig. 13

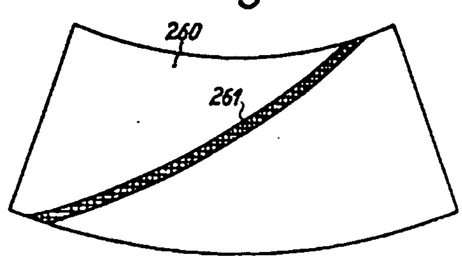

Fig. 14